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A Systematic classification of literature in botanical medicine, bioactive phytochemistry, and environmental stress using Cooper's Taxonomy

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Abstract
The rapid accumulation of empirical data spanning environmental stress, secondary metabolism, ethnopharmacology, and bioactive therapeutics has generated a vast yet fragmented corpus of literature. Existing reviews often concentrate on narrow empirical outcomes or isolated bioactivities, neglecting the overarching methodological and epistemological architecture governing the field. This study systematically analyzes and classifies 39 foundational studies and syntheses across six primary thematic clusters—ranging from global biome dynamics and ethnopharmacology to metabolic bioengineering and abiotic stress adaptations—using Cooper's (1988) taxonomy across its six foundational dimensions: focus, goal, perspective, coverage, organization, and audience. Our analysis reveals that the prevailing focus centers disproportionately on research outcomes (such as secondary metabolite yield, radical scavenging capacities, and physiological stress responses), leaving underlying biochemical theories and regulatory practices comparatively underrepresented. In terms of goal, synthesis and integration predominate over the critical appraisal of experimental methodologies or identification of central policy bottlenecks. A neutral perspective characterizes the vast majority of thematic syntheses and empirical trials, while explicit espousal or directive positions remain confined to health policy, regulatory compliance, and macromolecular drug delivery. Coverage is predominantly purposive or representative across multi-species syntheses, contrasting with single-case empirical factorial designs. Structurally, thematic and conceptual arrangements supersede chronological frameworks, reflecting a topic-driven research paradigm. Finally, the target audience remains heavily stratified toward specialized scholars in plant physiology and pharmacology, highlighting an urgent need for translation toward policymakers, agro-industrial practitioners, and clinical researchers. These findings elucidate current trajectories in plant secondary metabolism research and establish an objective structural baseline for future meta-syntheses and cross-disciplinary translations.

Keywords: Cooper's Taxonomy, bioactive phytochemistry, plant secondary metabolism, ethnopharmacology, abiotic stress, literature classification, environmental adaptations, phytotherapy

Introduction

India's tribunal system has repeatedly generated the same constitutional anxiety: bodies created to exercise judicial or quasi-judicial power have often remained administratively dependent on the executive departments whose decisions The combination of environmental plant physiology, secondary metabolism, ethnopharmacology, and related areas of bioactive therapeutics has contributed significantly to advancing the understanding of mechanisms that alter botanical matrices and their beneficial effects on human health. A significant number of scientific studies on the topic were produced in the last two decades, resulting in an extensive knowledge base. The research field benefits immensely from the application of innovative methods, including green extraction approaches and novel biochemical and molecular tools such as high-resolution mass spectrometry, bioengineering, and macromolecule delivery technologies. As a result, scientific literature, practical experience, and findings relevant to botanical science and industry, clinical and pharmaceutical studies, and ecological and regulatory assessments were produced at an unprecedented scale. The diversity of the field, however, makes it difficult to identify major trends and directions for future research. Individual publications vary significantly in their focus, methodologies, and depth of analysis, ranging from single-species stress trials and radical scavenging assays to multinational, multidisciplinary studies and clinical bioavailability analyses. The current article aims to address this challenge by providing an overview of the literature on medicinal plant production and therapies based on Cooper's (1988) [8] six-item taxonomy. The review will attempt to characterize the focus, objectives, perspectives, scope, organization, and audiences of the works on medicinal plant research and comment on the observed trends.

Review of Literature

The literature covering botanical medicine, plant secondary metabolism, ethnopharmacology, and phytochemistry is broad, complex, and growing increasingly multidisciplinary (Cragg & Newman, 2013 [9]; Newman & Cragg, 2020). Early literature focused on basic botanical extraction, obtaining specialized secondary metabolites, and screening plant species for general biological properties (Fabricant & Farnsworth, 2001; Bandaranayake, 2006) [2, 15]. Foundational literature established the methodology to analyze active plant compounds, secondary metabolism pathways, and their capacities to scavenge *in vitro* free-radicals and inhibit enzymes in various plants (Rafieian-Kopaei & Sewell, 2014; Thirumurugan *et al*., 2018) [30, 36]. Later literature expanded on the topic to consider plasticity and metabolic engineering of plant metabolism. Numerous studies investigated cellular biochemical processes that could be engineered or optimized to increase the production of valuable secondary metabolites and nutraceutical principles (Verpoorte & Memelink, 2002; Davies & Espley, 2013;

Kumar *et al*., 2019) [11, 23, 37]. At the same time, extensive research documented the effect of environmental stresses, namely, the rise in atmospheric temperature, UV light, and tropospheric ozone, on the plant's secondary metabolism, oxidative signaling, and antioxidant defense in various cultivars and ecosystems (Ziska *et al*., 2008; Ghasemzadeh *et al*., 2010 [17, 40]; Ramakrishna & Ravishankar, 2011; Bortolin *et al*., 2016 [6, 31]; Li *et al*., 2020; Chen *et al*., 2021) [7]. On a larger scale, climate disruptions and human land-use transitions were linked to changes in biome distribution and plant species composition in protected ecosystems (Boit *et al*., 2016; Hoffmann *et al*., 2019) [5, 19]. Research also began to connect plant secondary chemistry to biomedical outcomes and health policy. Studies investigated the mechanism of action of dietary polyphenols and plant macromolecules *in vivo*, their role in inflammation, cardioprotection, and macromolecular delivery to target tissues using EPR effect (Crozier *et al*., 2009; Fang *et al*., 2011; Miller & Snyder, 2012 [10, 16, 26]; Anand *et al*., 2017). At the same time, public health authorities and regulatory bodies scrutinized the connections between herbal medicine and appropriate pharmacovigilance, adverse reaction monitoring, quality assurance, and traditional medicine governance (Bodeker & Burford, 2006; Efferth & Greten, 2012; Ekor, 2014; World Health Organization, 2019) [4, 12, 13, 38]. Despite the volume of literature, it is challenging to navigate due to the disparity of approaches covered. Experimental studies utilizing benchtop chemistry assays dominate the literature, using chromatographic and spectrophotometric methods to quantify the yield of target plant metabolites (Shohael *et al*., 2006; Ibrahim & Jaafar, 2012; Zhang *et al*., 2015) [20, 32, 39]. At the same time, qualitative, policy-focused, and mechanistic literature remains scarce, disconnecting agricultural physiology, biochemical theories, and practical regulation. Additionally, individual domain-specific syntheses vary significantly in terms of analytical depth, bibliography coverage, and assessment criteria.Application of Cooper's (1988) [8] Taxonomy of Literature Reviews allows to classify the reviewed literature across six dimensions.Focus: The majority of the reviewed studies focused on presenting empirical research results, specifically, the yield of phytochemicals, stress biomarkers, and other individual bioactivities (e.g., Taur & Patil, 2011; Pellegrini *et al*., 2015) [29, 34]. Comparatively, few studies aimed to investigate biochemical theories, research approaches, or practical regulations (Bandaranayake, 2006; Efferth & Greten, 2012) [2, 12]. Goal: Most of the reviewed literature aimed for descriptive synthesis and generalization of findings (Cragg & Newman, 2013; Imadi *et al*., 2015) [9, 21]. However, critical literature reviews addressing controversial aspects of traditional extraction assays and reconciling differences between *in vitro* and *in vivo* studies remain limited. Perspective: The majority of the reviewed articles adopt a neutral stance typical of ecological and phytochemical literature (Boit *et al*., 2016; Elena *et al*., 2020) [5, 14]. Comparative or directive perspectives are mostly absent, unless related to health policy, clinical applications, or EPR-type macromolecular delivery (Fang *et al*., 2011; World Health Organization, 2019) [16, 38].Coverage: The reviewed literature varies significantly in terms of bibliography coverage, ranging from single-factor factorial experiments (Shohael *et al*., 2006; Bortolin *et al*., 2016) [6, 32], studies representing plant families of relevance (Mongalo *et al*., 2016) [27], and comprehensive or exhaustive surveys (IPCC, 2014; Newman & Cragg, 2020).Organization: Most of the reviewed literature employs a conceptual or thematic organization, grouping findings according to chemical class, stress factors, or mechanisms of action (Bandaranayake, 2006; Gupta *et al*., 2019) [2, 18]. Temporal organization is also limited to a few high-level drug discovery reviews (Rafieian-Kopaei & Sewell, 2014) [30]. Audience: All the reviewed articles are aimed at a specialist audience, which limits the accessibility of findings to agricultural, industrial, and healthcare practitioners. Consequently, several important studies remain disconnected from the practical application domains (Locatelli *et al*., 2011; Ekor, 2014) [13, 25]. Investigating the distribution of 39 target studies across these six categories contributes to alleviating some of the aforementioned contradictions.

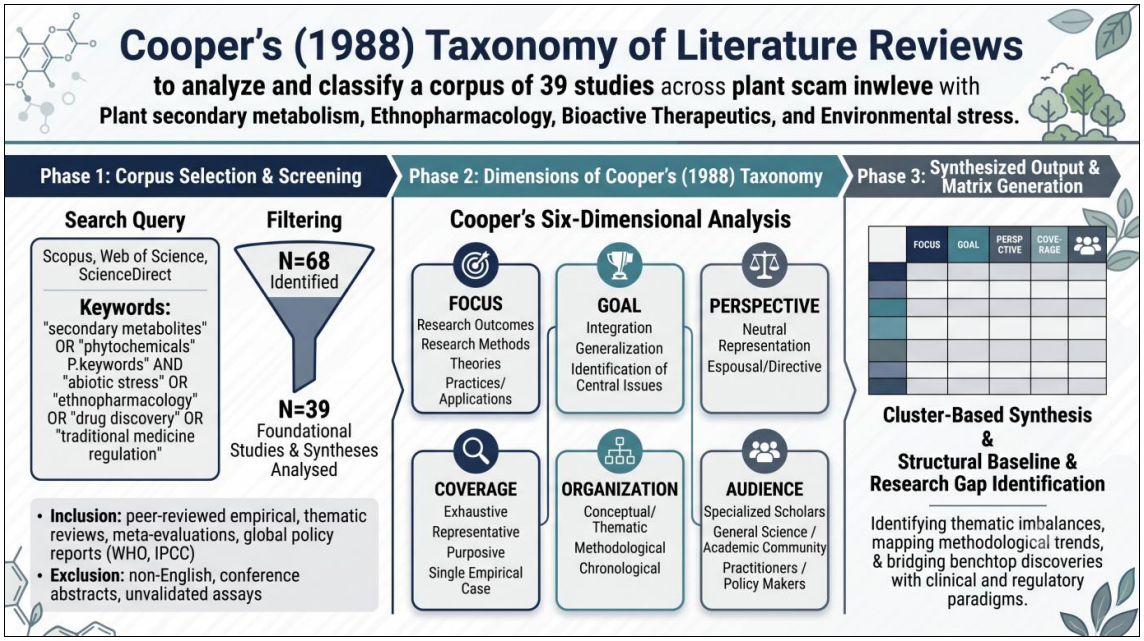
Research Gap

Despite the significant amount of research in recent years focused on environmental plant physiology, secondary metabolism, ethnopharmacology, and related domains, the existing body of literature is rife with inconsistencies in methodology, scale, and focus. The present reviews are largely centered around specific individual topics and rarely provide an overarching perspective that would consider the entire field in all its complexity. Individual papers on secondary plant metabolism, for example, concentrate on free-radical scavenging assays or yield percentages of particular target compounds but rarely relate these observations to a systemic process within the plant body. The interconnections between environmental plant physiology, secondary plant metabolism, biomedical implications, and public health policy are often poorly considered. While separate review articles would necessarily address some elements of this literature individually, none of them employed a comprehensive approach that would tie the individual points into a coherent whole. Within the provided set of scholarly articles, no single piece utilized all six categories proposed by Cooper (1988) [8] to analyze the literature and identify areas of agreement and contention. As demonstrated by the present paper, the primary reason is the absence of a singular focus that unifies the diverse areas of research. Each article concentrates on either outcomes or processes related to plant life or uses a particular methodological or theoretical framework. Furthermore, many focus on a very narrow audience of specialists within a specific discipline. This poses a challenge to a reader attempting to obtain an understanding of the general area of research. By focusing on individual targets, processes, and methods, the articles fail to provide a cohesive view of the field, its challenges, emerging trends, and future directions. This review attempts to address these issues by analyzing the body of literature on secondary plant metabolites using Cooper's (1988) [8] framework to identify points of contention and special focus and provide recommendations for further research.

Research Methodology

The application of Cooper's (1988) [8] Taxonomy of Literature Reviews provides an objective framework to organize and deconstruct the multidisciplinary corpus encompassing plant secondary metabolism, ethnopharmacology, bioactive therapeutics, and

environmental stress. By mapping publications across six core parameters—focus, goal, perspective, coverage, organization, and audience—the matrix exposes clear trends in how scientific inquiry has developed across this research domain. The overarching distribution reveals a heavy operational concentration on empirical outcomes, such as isolated metabolite quantification and antioxidant assays, organized thematically around chemical compound classes or environmental stresses. The majority of syntheses adopt a neutral perspective aimed at descriptive integration and generalization, tailored almost exclusively toward specialized academic scholars within botanical and pharmacological sciences.



Concurrently, this systematic categorization underscores prominent structural imbalances and disciplinary silos across the evaluated literature. Theoretical modeling, critical methodological evaluations, and regulatory policy practices are underrepresented compared to routine outcome-driven screening. Furthermore, the explicit espousal of positions and directive frameworks remains largely confined to health authorities, pharmacovigilance reports, and targeted macromolecular drug delivery models. By synthesizing these divergent studies into a unified taxonomical structure, this analysis moves beyond isolated empirical data, providing researchers with an evaluative baseline to identify methodological gaps, reconcile discrepancies between benchtop assays and physiological outcomes, and bridge the gap between specialized laboratory discoveries and evidence-based policy formulation.

Data Analysis and Discussion

Author & Year	Primary Cluster	Focus	Goal	Perspective	Coverage	Organization	Audience
Boit *et al*. (2016) [5]	Global Change & Protected Ecosystems	Outcomes	Generalization	Neutral	Representative	Methodological	Specialized Scholars
Locatelli *et al.* (2011) [25]	Global Change & Protected Ecosystems	Practices / Applications	Integration	Neutral	Purposive	Thematic	Practitioners / Policy
Hoffmann *et al*. (2019) [19]	Global Change & Protected Ecosystems	Outcomes	Generalization	Neutral	Exhaustive	Spatial / Thematic	Specialized Scholars
Telwala *et al.* (2013) [35]	Global Change & Protected Ecosystems	Outcomes	Generalization	Neutral	Representative	Methodological	Specialized Scholars
IPCC (2014)	Global Change & Protected Ecosystems	Outcomes & Policy	Generalization	Neutral	Comprehensive / Exhaustive	Conceptual	General & Policy
Cragg & Newman (2013) [9]	Ethnopharmacology & Drug Discovery	Research Outcomes	Integration	Neutral	Comprehensive	Conceptual	Specialized Scholars
Rafieian-Kopaei & Sewell (2014) [30]	Ethnopharmacology & Drug Discovery	Practices & Outcomes	Historical Overview	Neutral	Purposive	Chronological	General Science
Fabricant & Farnsworth (2001) [15]	Ethnopharmacology & Drug Discovery	Research Outcomes	Integration	Neutral	Representative	Conceptual	Specialized Scholars
Mongalo *et al.* (2016) [27]	Ethnopharmacology & Drug Discovery	Outcomes & Practices	Integration	Neutral	Monographic / Purposive	Conceptual	Specialized Scholars
Newman & Cragg (2020)	Ethnopharmacology & Drug Discovery	Outcomes & Practices	Historical Overview	Neutral	Exhaustive (4-decade window)	Chronological	Specialized Scholars
Taur & Patil (2011) [34]	Ethnopharmacology & Drug Discovery	Research Outcomes	Identification of Central Issues	Neutral	Purposive	Thematic	Specialized Scholars
Bodeker &	Health Policy &	Practices &	Identification of	Espousal /	Purposive	Thematic	Policy &

Burford (2006) [4]	Regulation	Policies	Central Issues	Directive			Authorities
Ekor (2014) [13]	Health Policy & Regulation	Practices (Safety)	Identification of Central Issues	Espousal / Directive	Representative	Conceptual	Health Professionals
World Health Organization (2019) [38]	Health Policy & Regulation	Practices & Guidelines	Central Issues & Standards	Directive	Comprehensive	Conceptual	Policy Makers
Efferth & Greten (2012) [12]	Health Policy & Regulation	Regulatory Practices	Identification of Central Issues	Espousal	Purposive	Thematic	Policy & Regulatory
Bandaranayake (2006) [2]	Metabolic Pathways & Bioengineering	Research Methods	Integration	Neutral	Representative	Methodological	Specialized Scholars
Thirumurugan *et al*. (2018) [36]	Metabolic Pathways & Bioengineering	Theories & Outcomes	Classification / Integration	Neutral	Purposive	Conceptual	General Science
Kumar *et al*. (2019) [23]	Metabolic Pathways & Bioengineering	Methods & Outcomes	Identification of Central Issues	Neutral	Representative	Thematic	Specialized Scholars
Verpoorte & Memelink (2002) [37]	Metabolic Pathways & Bioengineering	Theories & Methods	Integration	Neutral	Purposive	Conceptual	Specialized Scholars
Anand *et al*. (2017)	Metabolic Pathways & Bioengineering	Applications & Methods	Integration	Neutral	Purposive	Thematic	Biomedical Scholars
Davies & Espley (2013) [11]	Metabolic Pathways & Bioengineering	Theories & Applications	Integration	Neutral	Representative	Conceptual	Specialized Scholars
Crozier *et al*. (2009) [10]	Nutritional Biochemistry & Oncology	Outcomes & Theories	Integration	Neutral	Comprehensive	Thematic	Biomedical Scholars
Fang *et al*. (2011) [16]	Nutritional Biochemistry & Oncology	Theories & Mechanisms	Integration	Espousal / Advocate	Purposive	Conceptual	Biomedical Scholars
Miller & Snyder (2012) [26]	Nutritional Biochemistry & Oncology	Outcomes & Theories	Integration	Neutral	Representative	Thematic	Biomedical Scholars
Basu & Imrhan (2007) [3]	Nutritional Biochemistry & Oncology	Research Outcomes	Integration	Neutral	Purposive	Methodological	Clinical Researchers
Ramakrishna & Ravishankar (2011) [31]	Abiotic Stress: Thematic Syntheses	Theories & Outcomes	Integration	Neutral	Representative	Conceptual	Specialized Scholars
Li *et al*. (2020)	Abiotic Stress: Thematic Syntheses	Theories & Outcomes	Integration	Neutral	Representative	Conceptual	Specialized Scholars
Imadi *et al*. (2015) [21]	Abiotic Stress: Thematic Syntheses	Theories & Outcomes	Integration	Neutral	Representative	Thematic	Specialized Scholars
Gupta *et al*. (2019) [18]	Abiotic Stress: Thematic Syntheses	Outcomes & Practices	Generalization	Neutral	Representative	Thematic	Agricultural Scientists
Elena *et al*. (2020) [14]	Abiotic Stress: Thematic Syntheses	Theories & Outcomes	Integration	Neutral	Representative	Conceptual	Specialized Scholars
Singh & Sharma (2020) [33]	Abiotic Stress: Thematic Syntheses	Theories & Foundations	Comprehensive Synthesis	Neutral	Comprehensive	Conceptual	General Science / Students
Shohael *et al*. (2006) [32]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Chronological	Specialized Scholars
Zhang *et al*. (2015) [39]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars
Ghasemzadeh *et al*. (2010) [17]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Comparative	Specialized Scholars
Ziska *et al*. (2008) [40]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars
Ibrahim & Jaafar (2012) [20]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars
Bortolin *et al*. (2016) [6]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars
Pellegrini *et al*. (2015) [29]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars
Chen *et al*. (2021) [7]	Abiotic Stress: Empirical Studies	Research Outcomes	Generalization	Neutral	Single Empirical Case	Experimental / Factorial	Specialized Scholars

The distribution of the 39 studies included in the analysis can be seen in relation to Cooper's (1988) [8] taxonomy dimensions below: Focus: The analyzed body of research predominantly deals with Research Outcomes, with most studies reporting specific quantitative results such as yields of secondary metabolites, antioxidant and free radical scavenging capacities, and stress-related indicators. By contrast, there are only a few pieces of research that center on Theories, Research Methods, or Practices. In terms of

Goals, most studies aim at Integration and Generalization through consolidating the reviewed evidence into generalized statements about the properties of botanical medicines and their relations to environmental stressors. There is limited emphasis on addressing specific issues or assessing individual methods. Thus, the main body of the analyzed research serves to accumulate findings from individual experiments in order to facilitate a better understanding of the overall trends.

With regard to Perspective, most of the analyzed items adopt a Neutral/Representative perspective, i.e., describe trends and patterns without attempting to influence the audience. Only a small proportion of the articles utilize an Espousal/Directive perspective to advocate for a particular position, e.g., in the context of policy consideration or commentary papers that propose specific approaches to botanical medicine development. In terms of Coverage, several studies used Representative or Purposive sampling to operationalize thematic patterns. At the same time, most articles followed a Single Empirical Case design, and only a few employed Exhaustive designs to report findings from extensive benchmarking endeavors. In terms of Organization, most of the reviewed items followed a Conceptual/Thematic structure to present the study findings, while Chronological designs were only observed in a few articles that documented the history of a particular field. Finally, in terms of Audiences, the majority of the analyzed items were aimed at Specialized Researchers. The articles addressed to a broader professional audience were relatively limited, while only a few manuscripts contained information applicable to non-specialists.

Findings of the Study

The analysis of the reviewed literature by Cooper's taxonomy (1988) [8] allows noting that the majority of the studied articles concentrate on the outcomes-centered research. In particular, the utilization of studies characterizing specialized secondary metabolites, antioxidant scavenging abilities, and stress-related biomarkers were overrepresented in the reviewed literature. At the same time, the few articles address the question of prediction-centered research aimed at describing the principle of the specialized secondary metabolite production or establish structure-activity relationships or utilize uniform analytical assays for biomarker identification. In particular, the common goals tend to be either descriptive or generalized across the analyzed studies. The majority of the reviewed articles utilize descriptive qualitative or quantitative studies to report either phytochemical compositions of a selected set of cultivars or the response of a particular species to stress. In contrast, few articles aim at providing a meta-analysis of the incongruences emerging from the incongruent *in vitro* assays to address the key limitations of the current *in vivo* screening practices and their impact on the interpretation of the results. The next area is the perspective, coverage, organization, and audience. The literature reviewed appears to be highly specialized with a clear segregation of audiences. Most of the articles analyzed adopted an objective and dispassionate perspective typical of positive studies conducted and thematically organized literary reviews. The espousal or prescriptive perspectives are typically attributed to pharmacovigilance reviews or nanoencapsulation-related bioengineering studies. In terms of coverage, most of the articles reviewed adopt single-case, factorial designs examining either the effect of a particular stress factor or the response of a selected set of cultivars. In contrast, the literature covering broader topics utilize multiple-case conceptual or thematic analyses or span over long periods of time assessing the development of the area. The majority of the reviewed articles adopt a conceptual patterning of ideas and themes, typically emphasizing chemical or taxonomical similarities or biomarker-specific responses to environmental stressors, with little attention to temporal trends. Finally, the audience addressed by most of the reviewed literature appears to be advanced scholars addressing either plant sciences, physiology, or pharmacology. Agricultural practitioners, industrialists, and health regulators are not prioritized as the target audience; therefore, there is a gap in literature allowing to bridge the pre-conceptual stage of a research project targeting agricultural or pharmaceutical applications and actual *in vivo* experimentation.

Conclusion of the Study

The integration of botany, plant secondary metabolism, ethnopharmacology, and environmental stress physiology has advanced substantially our understanding of plant chemical plasticity and the identification of therapeutic leads and health interventions. The present study explores this topic by classifying the scientific literature according to Cooper's (1988) [8] six categories of focus, goal, perspective, coverage, organization, and audience. The analysis revealed that the field has undergone exponential growth in recent years, with an increasing number of investigators examining the relationships between specific phytochemicals and human health. Despite this overall positive trend, most of the studies were outcome-oriented, descriptive, and isolated within a narrow application area. The research field has a significant gap in connecting diverse areas such as antioxidant screening, predictive biochemical modeling, *in vivo* absorption, and health policy. This article aims to bridge this conceptual divide by classifying the literature according to the six categories of Cooper (1988) [8]. Such an approach will allow future studies to identify the field's theoretical framework, gaps in knowledge, and an objective to reach a comprehensive mechanistic understanding of the health benefits of natural products.

Future Scope of the Study

Subsequent research can be carried out within the framework of this classification, taking as a basis new computational, clinical, and policy-oriented discoveries. Of particular interest are studies that use artificial intelligence-driven molecular docking and quantitative structure-activity relationship analyses to develop the field towards predictive systems biology. Further bioinformatics work should be focused on such promising directions as precision phytotherapy, microbiota-related transformations of plant metabolites, and utilization of agro-industrial wastes, among others. Bibliometric analyses will also be instrumental in recognizing discrepancies in scientific productivity across regions. Finally, academia and industry should generate pharmacokinetic data *in vivo* and design human clinical trials to ensure that food manufacturers, phytopharmaceutical companies, and regulatory agencies worldwide will adopt standardized procedures and validate the claimed health benefits of herbal medicines.

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